These integrals are given in the first three cases, and the formula for finding the last, which is somewhat complicated, furnished.

Finally, it is shown that the results may be transferred to the case of a planetary ellipsoid by changing, in the formulæ, ϵ into $-\epsilon$.

II. "On a New Method of Investigating the Magnetic Lines of Force in Magnets, demonstrating the Obliquity of the Equator and Axis of Bar Magnets." By Richard C. Shettle, M.D. Communicated by Dr. Royston-Pigott, F.R.S. Received April 24, 1879.

It was not until some thousand observations had been made in the manner about to be described, that I was rewarded with the discovery of the obliquity of the bar magnetic equator, which is the subject of the present communication.

On a former occasion the Royal Society did me the honour of accepting a similar research on the magnetic condition of arterial and venous blood.

My present object is to detail the manner in which I have been led up to the result now obtained.

It appeared to me that the usual method of displaying magnetic currents by means of the curves assumed by steel filings were only rough approximations.

Long after I had been occupied with these observations I became aware, through the kindness of Professor Stokes, Secretary to the Royal Society, that Sir George Airy, the Astronomer Royal, had in a short paper in the "Transactions," investigated (with a pocket compass furnished with a magnetic inch-needle) these lines of force. The method which I have adopted is essentially different, and greatly exceeds in delicacy.

1*st.*—*Inch magnetized steel needles were suspended and nicely balanced on a single silk fibre* 6 *inches long.*

These needles carried over the magnets assumed rapidly changing positions, and readily demonstrated, as in the paper alluded to, the varying force and direction as usually portrayed in treatises on magnetism. But these long needles utterly failed in the niceties of research on which I was employed.

2*nd.*—*Needles varying from half an inch to the* 1–16*th of an inch were mounted and suspended in a similar manner.*

I found the latter thoroughly competent to trace sudden changes in

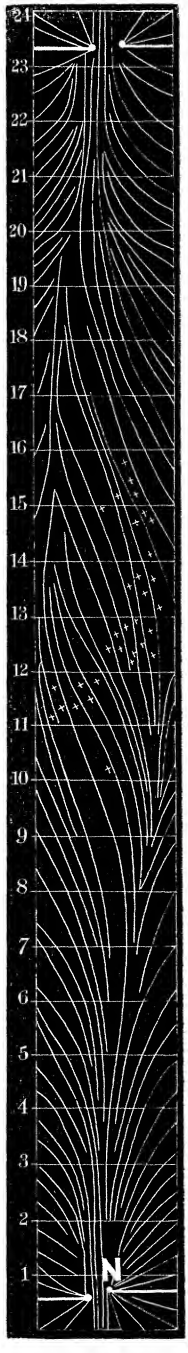

Fig. 1.

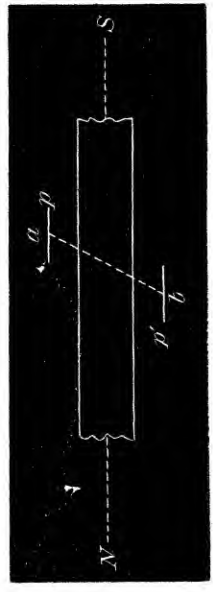

Fig. 3.

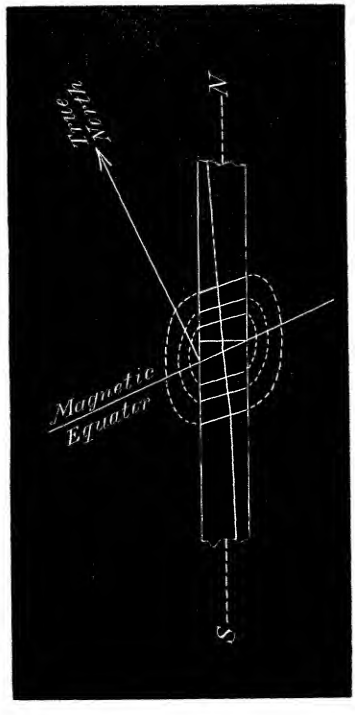

Fig. 2.

the magnetic forces. And, for the purpose of recording the curves so traced out, I covered the surfaces of some bar-magnets with paper, and then ruled lines on them 1–16th of an inch apart, longitudinally as well as transversely.

The squares so formed gave exact co-ordinates for reference.

Next, the position of the suspended needle 1–16th of an inch long, or 1–8th if the curves displayed no sudden curvature, was carefully plotted in each of these squares by means of a hand lens. The accumulation of all these plottings, on careful continuation, gave the curves, as traced from pole to pole, shown in fig. 1.

The equatorial regions adjacent to the centre of the magnets examined were plotted by dotting down the exact position of the suspended minim magnet in its ultimate state of stable equilibrium; these dots were then assiduously joined by a continuous line.

In selecting the initial positions of the extraneous curves, equidistant lines were drawn parallel to the bar, and points were simultaneously elected on two equidistant lines from which to start equatorial curves, such as *a* and *b* in the fig. 3.

In every case the points of parallelism of the test needles in these equidistant lines upon being joined by a straight line P P′, exhibited *obliquity*.

But the principal obliquities are demonstrated by joining the points of contact with the bar of the curves fully traced out from these equidistant points, such as P P′.

These curves may be described *as those whose tangents are parallel to the axis of the* bar N S, at points equidistant from it (fig. 2).

According to the curvature, changing slowly or rapidly, a different set of needles is employed, which are preserved, ready for use, in glass tubes.

The work is one requiring great steadiness of manipulation. Some thousands of observations require plotting on a minute scale. Indeed, innumerable curves of great extent and variety have been plotted upon the surface of magnetic bars covered with paper, as seen in fig. 1.

Not only were these curves traced all over the surface of the magnets, but they were also traced a considerable distance away from them laterally.

The nature of these extraneous or lateral curves appears graphically hyperbolic. Any given curve thus formed is the position of the magnetic needle traced from point to point, which needle is necessarily under the influence of both the terrestrial and the bar magnetism for the time being, and its direction is *a resultant of the various forces* bringing it to a state of rest at the various points examined.

One of the most striking results of the investigation, when the curves are placed very near the centre of the bar, is the *general obliquity of the magnetic equator of the bar* (fig. 2).

This obliquity of the magnetic equator of the bar is demonstrated by the *coup d'œil* of the curves traced out magnetically, as shown in fig. 1.

The magnetic lines are the outcome of some thousand observations.*

The oblique convergency of the magnetic lines towards the north and south poles is strongly pronounced, and a neutral zone was discovered, which is indicated in fig. 1 by crosses + +.

The region of this neutral zone was explored by examining all those points where the suspended magnetic particle of steel exhibited indifference, either of its poles being observed to be equally attracted.

This interesting experiment can be far better appreciated by actual observation than by description, and is best shown perhaps by carrying the 1-4th inch test-magnet from the north towards the south pole across the equator. When over the north side of the equator the south pole dips; if it be then allowed to fall upon the bar, and is raised again, the south pole will leave the bar last. When it has been carried south across the equator the north pole dips, but if it be again allowed to fall upon the bar, and is once more raised, the south pole will leave the bar last, just as it did on the north side of the equator.

But this novel feature of an oblique zone is more beautifully displayed by examining small curves, traced out in the way indicated, by the smallest test-magnets near the geometrical centre of the bar, for lines equidistant from its axis.

The obliquity (measured as close as possible to the bar by means of curves traced out so as to enter the two sides of the bar) has a very equable value, varying according to the nature of the magnet, as regards the intensity of the magnetism, the quality of the material, and its temper, from 7° to 10°; and this result is confirmed by the investigation of the internal curves of many thousand observations on magnets from $7\frac{1}{2}$ to 18 inches long. Indeed, it was the invariable inclination of the surface lines which suggested the equatorial obliquity.

* The principle of squares was adopted in the enlargement: a lens being employed on the original chart.

Fig. 1.

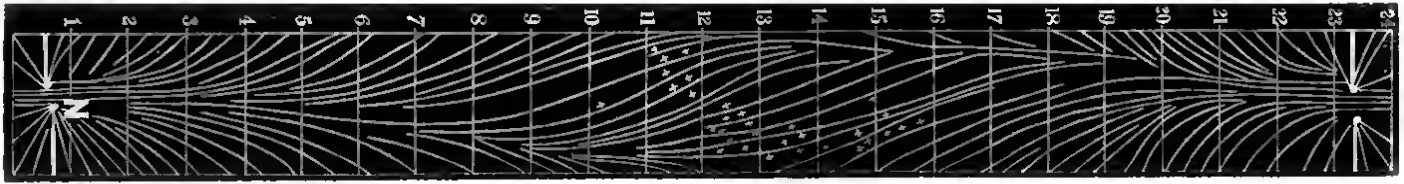

FIG. 2.

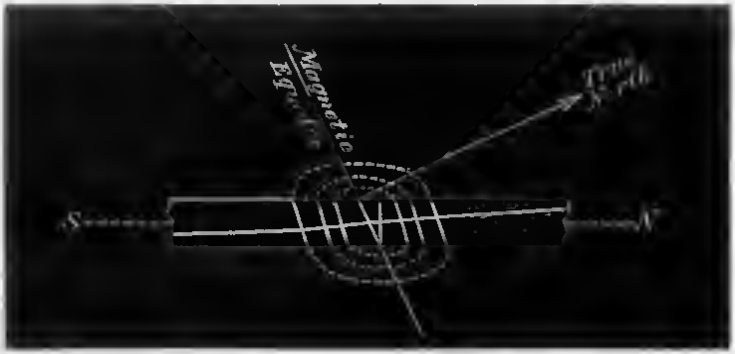

FIG. 3.